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Studies on the Control of Cabbage Caterpillars With Derris in the South

By W. J. REID, JR., assistant entomologist, C. E. SMITH, associate entomologist, L. B. REED, associate entomologist, and C. O. BARE, assistant entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine¹

The United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, in Cooperation with the Agricultural Experiment Stations of Louisiana and South Carolina

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INTRODUCTION

Cabbage, a crop of major commercial importance in many localities in the South, is often seriously damaged by one or more of the following species (fig. 1) of lepidopterous larvae: The cabbage looper (*Autographa brassicae* (Riley)), the diamondback moth (*Plutella maculipennis* (Curtis)), the imported cabbageworm (*Pieris rapae* (L.)), and several species of the subfamily Agrotinae.² Until recent years arsenicals were used extensively in combating these pests, and it was frequently necessary to apply the insecticides after marketable parts of the plants were exposed. Sudden and heavy cabbage caterpillar outbreaks usually occur on maturing crops and under conditions unfavorable for the removal of arsenicals by natural agents, with the result that serious marketing difficulties have been experienced owing to excessive poisonous residues.

¹ W. J. Reid, Jr., and C. E. Smith were in direct charge of the investigations at Charleston, S. C., and Baton Rouge, La., respectively. Acknowledgements for assistance are made to C. F. Stahl, who had general supervision of the cabbage insect work in the South, and to Ross W. Brubaker and P. K. Harrison, who assisted at Baton Rouge, La.

² Several species of true cutworms and the corn earworm (*Heliothis armigera* Hbn.) will be considered as a group and referred to as Agrotinae in this circular.

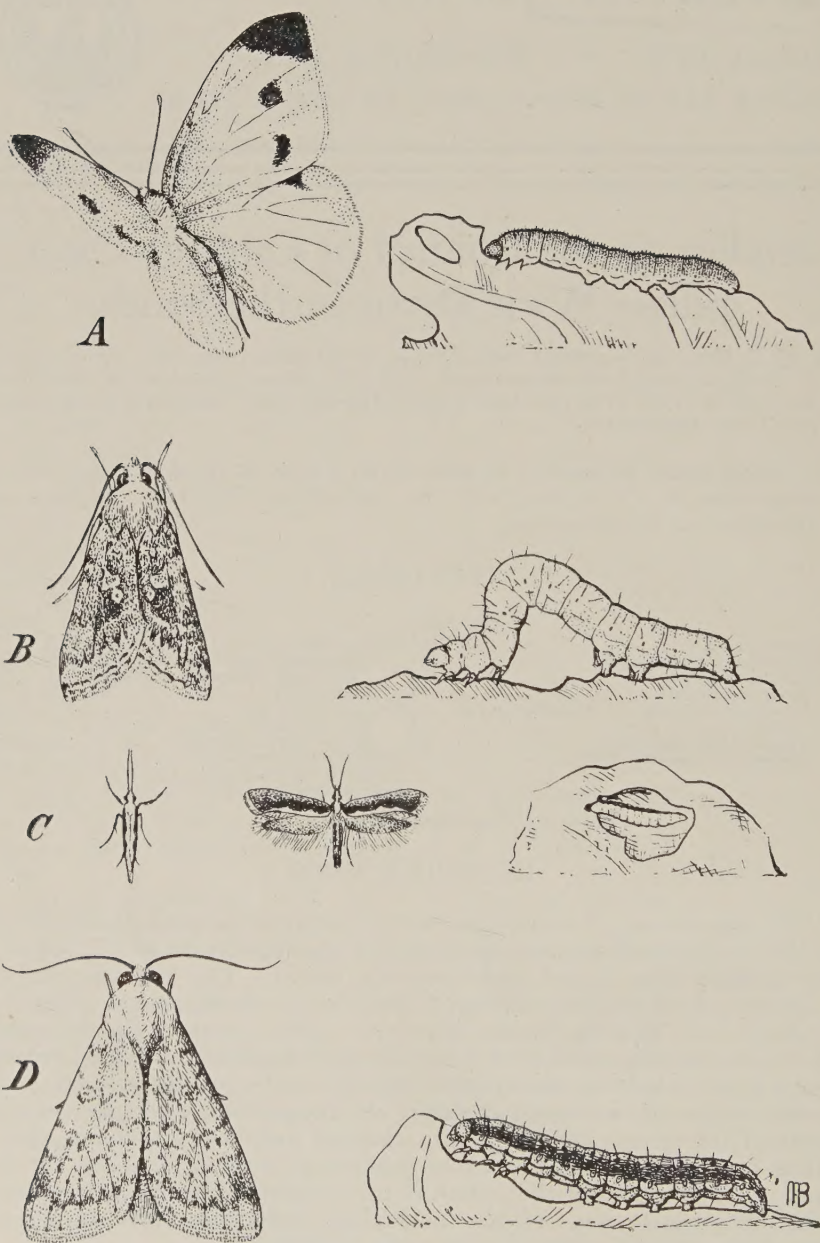


FIGURE 1.—Adults and larvae of cabbage caterpillars: A, The imported cabbage-worm; B, the cabbage looper; C, the diamondback moth; D, the corn earworm. Slightly enlarged.

To alleviate this situation the Division of Truck Crop and Garden Insect Investigations of the Bureau of Entomology and Plant Quarantine in 1932 made the study of cabbage caterpillars the major activity at the laboratories at Baton Rouge, La., and Charleston, S. C. The phases of the activity that received early attention included a study of the limitations in the use of arsenicals on cabbage and a study of the comparative effectiveness of materials that could be substituted for, or used in conjunction with, arsenicals and fluorine compounds. Results of these earlier investigations have been published by White (11),³ by Smith et al. (8), and by Reid et al. (6).

In these early studies it was demonstrated that arsenicals could not be applied to cabbage plants after they had begun to form heads without incurring the risk of having residues on the marketed product which would exceed the legal tolerance. In a search for materials less objectionable from the standpoint of dangerous residues it was found that derris and pyrethrum powders, applied as dusts, were usually as effective as, and often superior to, the arsenical or fluorine compounds in reducing infestations of the three most important species of cabbage caterpillars, namely, the cabbage looper, the diamondback moth, and the imported cabbageworm. Derris appeared to be the most effective of these two materials under all conditions encountered. Of the derris dilutions compared, that containing 0.5 percent of rotenone showed greatest promise for general use, except against unusually high populations of the cabbage looper. In general, similar contemporaneous results were obtained by Hervey and Palm (3), who also reviewed the early literature on the use of derris and pyrethrum for cabbage caterpillars, by Hamilton and Gemmell (2), Hockett (4), Walker and Anderson (9, 10), List and Sweetman (5), Roney and Thomas (7), and Gui and Slesman (1).

As a result of these findings information was needed concerning the number and schedule of applications of derris dust necessary to protect cabbage from caterpillar damage, and the economic value of such measures. To obtain this information the investigations described in this circular were undertaken.

DESCRIPTION OF THE EXPERIMENTS

CULTURAL PRACTICES

The methods of cabbage culture practiced by growers and considered to be best adapted to the locality were employed at each laboratory. The Charleston Wakefield variety of cabbage was used in all the experiments at Charleston, S. C., and the Copenhagen Market variety at Baton Rouge, La.

In the South cabbage is often grown in a succession of plantings requiring attention from late in July to early the following June. The cabbage is harvested as two crops, one late in the fall and early in the winter, the other in the spring, and on this basis they will be designated as the fall and spring crops, respectively. The fall crop

³ Italic numbers in parentheses refer to Literature Cited, p. 25.

is usually seeded directly in the field rows from late in July to early in September and is harvested from late in October through January. The spring crop is grown almost entirely from plants that are seeded in plant beds in October, transplanted into field rows from November through the early part of February, and harvested from March through the first week in June.

In harvesting cabbage, individual heads are cut as they become solid and otherwise suitable for market. Survey studies have shown that the heads within a single field may reach maturity over a period of from 3 to 12 weeks, depending on the season and weather conditions. When this period is prolonged beyond 4 or 5 weeks, the later cuttings often involve such small numbers of heads that they are of minor importance. Ordinarily the harvest period for a single field extends over a period of about 4 weeks. Commercial cuttings are made at irregular intervals, depending on growing conditions and the market price.

SCOPE OF EXPERIMENTS

To show the practical benefits to be obtained from the use of the derris dust at various times, the yield of marketable cabbage and extent of caterpillar damage from the plots receiving different numbers of applications were compared. Examinations sufficient to indicate the intensity of the infestations of the various species of insects involved were included in the procedure. To obtain the desired locality replication, the experiments were conducted simultaneously at Baton Rouge, La., and at Charleston, S. C. Nine experiments were completed, two at Charleston and one at Baton Rouge during the fall of 1935, and one at each locality during the spring and fall of 1936 and the spring of 1937.

INSECTICIDE MATERIALS AND METHOD OF APPLICATION

A dust mixture of derris-root powder and clay containing 0.5 percent of rotenone was the insecticide used, because in preceding field toxicity tests this dilution had been found to be only slightly less toxic than mixtures containing greater percentages of rotenone, and was more toxic than the other materials to combined populations of the prevailing species except those belonging in the subfamily Agrotinae. To combat the Agrotinae a dust composed of 1 part, by weight, of paris green and 9 parts, by weight, of hydrated lime was used during the preheading stage of plant development in the fall experiment of 1936 at Charleston. The necessity of special effort during fall seasons to control the Agrotinae in that area on plants that have passed the seedling stage was not apparent until brought out by studies in the fall of 1935.

For each experiment fresh supplies of ground derris-root powder were obtained from reliable dealers, and samples were analyzed by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine before the dusts were mixed. The rotenone and carbon tetrachloride-extractives contents of the different lots of derris-root powder used in all experiments are given in table 1.

TABLE 1.—*Rotenone and carbon tetrachloride-extractives content of the various lots of derris-root powder used in field experiments for the control of cabbage caterpillars at Baton Rouge, La., and Charleston, S. C., 1935-37*

Derris-root powder used in—	Rotenone content	Total material soluble in carbon tetrachloride ¹
	Percent	Percent
Fall of 1935.....	4.1	17.1
Spring of 1936.....	4.4	18.4
Fall of 1936.....	4.4	18.4
Spring of 1937.....	5.1	16.8

¹ Including rotenone.

China clay was used for diluting the derris powder, and just before they were applied the dusts were mixed in the type of sifting and mixing machine shown in figure 2. The applications were made late in the afternoon or early in the evening, when there was usually a minimum of air movement and in some cases moisture was con-

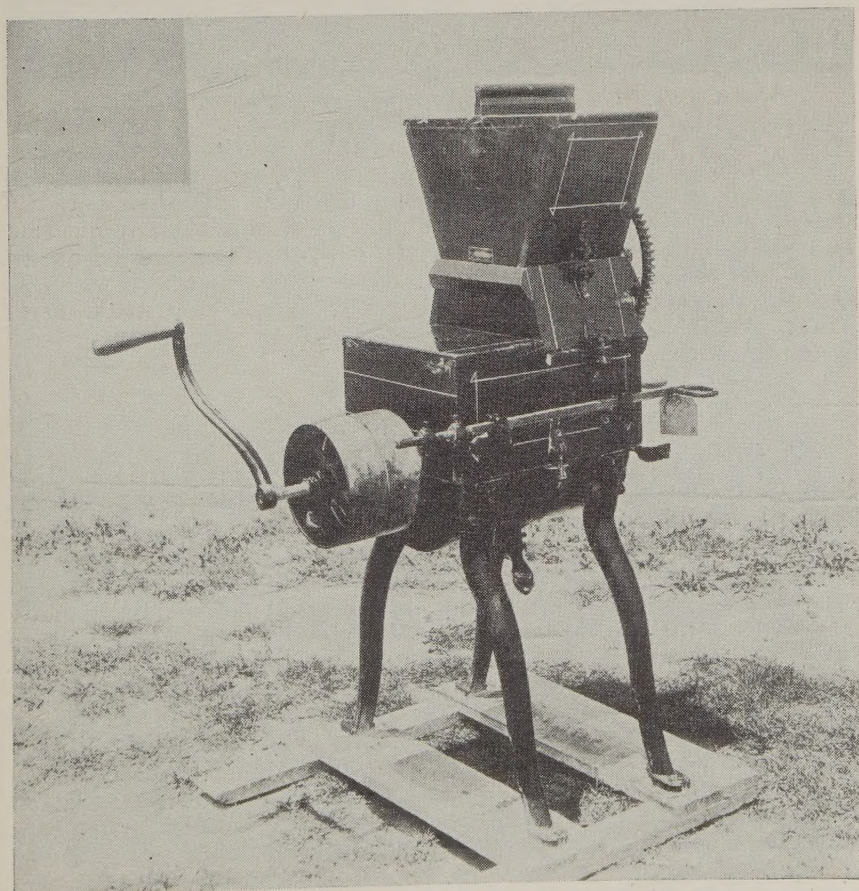


FIGURE 2.—Type of sifting and mixing machine used in the preparation of dusts.

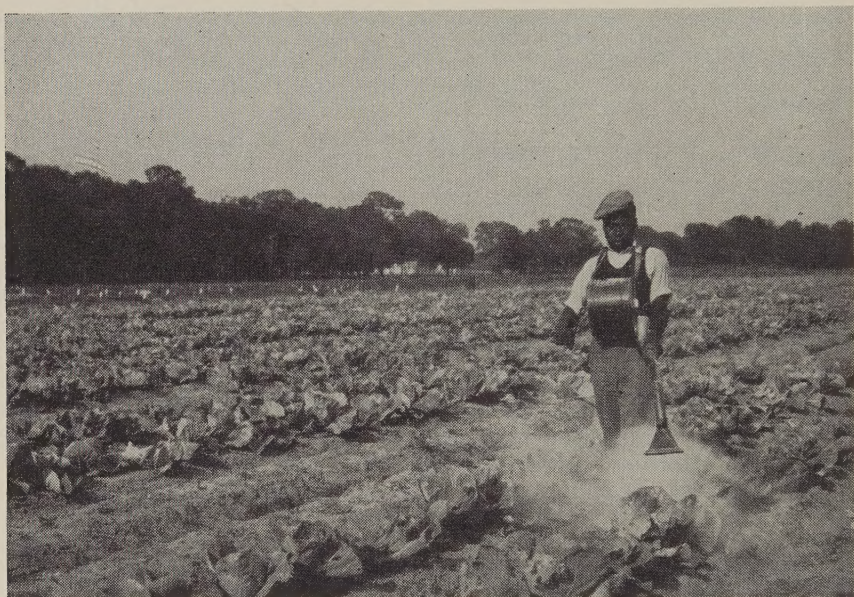


FIGURE 3.—Type of rotary, hand dust gun used in the application of insecticides.

densing on the plants. Rotary, hand dust guns of the type shown in figure 3 were used to apply the dust mixtures. To distribute the dust thoroughly one trip was made per row during each application before the plants began to form heads, with the dust directed downward into the buds of the plants, and two trips per row with the dust directed diagonally into each side of the plants were made thereafter. A cabbage plant that was considered in this study to have begun to head is illustrated in figure 4.

DESIGN OF THE EXPERIMENTS

The six different experimental treatments that were compared involved the use of from none to five applications of the 0.5-percent-rotenone dust during what was considered the experimental period, this period extending from the thinning or transplanting of the plants until the beginning of their harvesting. The interval between applications was one-sixth of the experimental period, and usually was about 10 to 12 days. In several instances it was necessary to use insecticides to protect the plants at times other than those included in the experimental period, and in these cases the entire planting was dusted, including the check treatment, except in the experiment of the spring of 1936, when the check was not dusted.

Each of the 6 experimental treatments was replicated on 6 different field plots in each experiment, the 36 plots of each experiment being arranged in a Latin square and a different random assignment of treatments to plots being used in each experiment.

The plot design was the same for all experiments. A plot consisted of four 50-foot rows of cabbage. At Baton Rouge the rows

were 40 inches wide, and the plants 18 inches apart, and at Charleston the rows were 36 inches wide and, unless stated otherwise, the plants 15 inches apart. Insecticide dosages and plant yields were calculated on the basis of a 36-inch row at both locations. An unplanted strip 3 feet wide separated the ends of adjacent plots. The entire 50-foot length of all rows was dusted, but the sampling area from which data pertaining to caterpillar populations and to plant yields were obtained consisted of the inner 44 feet of the 2 middle rows of each plot. This area contained approximately 60 plants at Baton Rouge and approximately 70 plants at Charleston.

In each of the nine experiments one treatment area (six plots) was left undusted during the entire experimental period, one treatment area received one application of the 0.5-percent-rotenone dust, and the others received two, three, four, and five applications, respectively. The experiments at the two locations were designed to function as both locality and seasonal replicates, and this plan was carried out in seven of the nine experiments. In each of the four experiments at Baton Rouge, and in the two spring-crop experiments and the



FIGURE 4.—Cabbage plant of Charleston Wakefield variety considered as beginning to form a head.

first of the fall-crop experiments at Charleston, the treatment area that received only one application during the experimental period was dusted at the end of the period, i. e., shortly before harvest began; the area receiving two applications was dusted about 12 days earlier and again just before harvest, and the first applications for the others were similarly scheduled 12 days earlier than the preceding, which resulted in the areas getting five applications being dusted about every 12 days during the entire experimental period.

After the first fall-crop experiment, that of the 1935 season, was under way at Charleston it was evident that the fall crops in that area needed greater protection during the early part of the experimental period than during the latter part. Consequently, in another experiment of that season and in the one experiment of the following fall season the dusting schedule used was the reverse of that described in the preceding paragraph. This meant that the treatment area receiving only one application was dusted at the beginning of the experimental period, the one receiving two applications was dusted at the same time and also about 12 days later, and so on as regards the other treatment areas.

METHODS OF EVALUATING RESULTS

CATERPILLAR POPULATIONS

An estimate of the relative abundance of the different species of caterpillars during the various experiments was obtained by counting the number of insects on four plants (within the sampling area) of each of the undusted check plots shortly before each insecticide application.

PLANT YIELDS

The evaluation of the various experimental treatments was based on plant yields. All plants within the sampling areas of the plots were harvested at weekly intervals as they matured and were graded according to a classification⁴ based on United States Standards for Cabbage and designed to indicate the degree of caterpillar injury received by the plants, as well as other conditions affecting their market values.

DETAILS OF HARVEST CLASSIFICATION

According to the Standards for Cabbage recommended by the Agricultural Marketing Service, United States Department of Agriculture,⁵ cabbage is classified as U. S. No. 1, U. S. Commercial, and Unclassified. The term "Unclassified" is not a grade name but is provided as a description to show that no definite grade has been applied to the lot. To be graded as U. S. No. 1, the cabbage must be free from damage by worm injury. The U. S. Commercial grade

⁴ REID, W. J., JR. A SYSTEM OF CLASSIFYING CABBAGE ACCORDING TO THE EXTENT OF CATERPILLAR INJURY. U. S. Bur. Ent. and Plant Quar. Cir. ET-160, 4 pp., illus. 1940. [Mimeographed.]

⁵ KITCHEN, C. W. U. S. STANDARDS FOR CABBAGE (EFFECTIVE DECEMBER 20, 1939). U. S. Dept. Agr., Agr. Market. Serv. 4 pp. 1939. [Processed.]

is the same as U. S. No. 1 except for an increased tolerance for defects.

There is a distinction between the terms "damage" and "injury" as used in the United States Standards for Cabbage and in this paper. Damage refers to caterpillar injury which is of such a nature or extent as to cause a plant to be ineligible to the U. S. No. 1 or the U. S. Commercial grades. Probably the most important factor involved in the classification was the matter of deciding just when caterpillar injury or injuries should be considered as damage. Information regarding the market grading of cabbage was obtained from the Agricultural Marketing Service, and practical demonstrations of grading procedure by licensed inspectors of the Marketing Service were witnessed by the writers before the grading of the experimental plants was begun.

Among other requirements for the U. S. No. 1 and the U. S. Commercial grades there must be not more than four loose outer or wrapper leaves, unless the crop is to be sold under the subgrade "U. S. No. 1 Green," which permits as many as seven wrapper leaves. The classification described herein is based on the appearance of the firm head and four wrapper leaves, with suitable classes provided for those plants which did not produce such a head. To allow fair comparisons of the various experimental control treatments as to numbers of plants produced, the classification did not permit the stripping of outer leaves to less than four. Stripping of the outer leaves to less than this number in order to eliminate insect injury is sometimes done in commercial practice, but such a procedure was not considered desirable in the experimental work.

In commercial grading, any single container of cabbage of a particular grade may contain a certain maximum percentage, by weight, of heads not meeting the requirements of the grade. This tolerance factor was given consideration in designing the classification described herein, but it was decided that it would be desirable in experimental work to grade each plant on its individual merits, to place it in a class consisting only of plants of similar quality, and to disregard the tolerance allowance. Insect damage is only one of the several defects that cause cabbage to be ineligible to the U. S. No. 1 grade, and the proportion of insect damage to the other defects varies greatly in different plantings. The assignment of any portion of the tolerance to insect damage would therefore have to be done on a rather arbitrary basis.

THE CLASSES

The classes as delimited for the evaluation of insect injury in the present study were as follows:

Class 1.—Plants whose firm head and four wrapper leaves are free from visible caterpillar injury, and in other respects are eligible to U. S. No. 1 grade.

Class 2.—Plants whose firm head and four wrapper leaves show caterpillar injury insufficient to be classed as damage, and in other respects are eligible to U. S. No. 1 grade.

Class 3.—Plants ineligible, because of caterpillar damage, to U. S. No. 1 grade:

(a) Those having firm heads;

(b) those not having firm heads.

Class 4.—Plants from which U. S. No. 1 grade cabbage cannot be obtained because of defects other than caterpillar damage.



FIGURE 5.—*A*, Typical class 1 heads and wrapper leaves of the Charleston Wakefield variety of cabbage without visible caterpillar injury, and in other respects eligible to U. S. No. 1 grade; *B*, typical class 2 heads with visible caterpillar injury but not classed as damaged and in other respects eligible to U. S. No. 1 grade.

Plants considered to be eligible to the U. S. No. 1 grade (classes 1 and 2) are illustrated in figure 5; plants regarded as not being eligible to that grade because of caterpillar damage (subclasses 3a and 3b) are illustrated in figures 6 and 7; and plants (class 4) from which, as a result of defects other than caterpillar damage, U. S. No. 1 grade cabbage cannot be obtained are illustrated in figure 8.

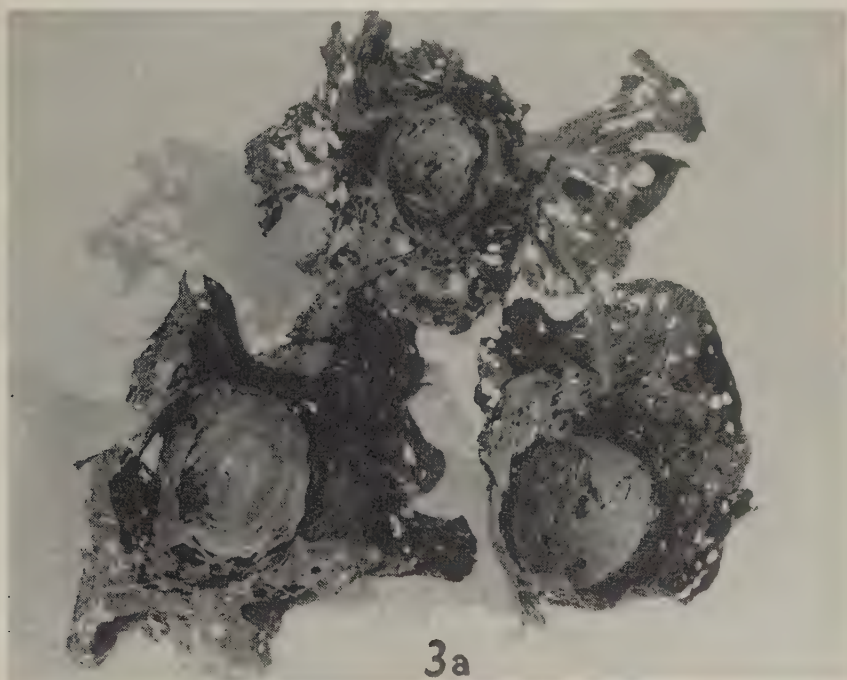


FIGURE 6.—Subclass 3a heads and wrapper leaves of Charleston Wakefield variety of cabbage showing caterpillar injury classed as damage.

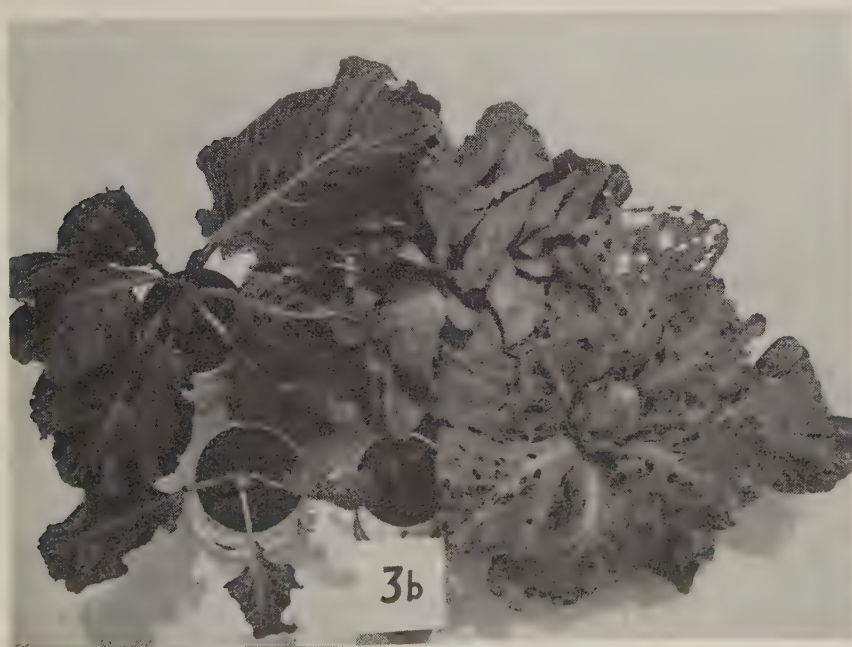


FIGURE 7.—Subclass 3b plants of Charleston Wakefield variety of cabbage damaged by caterpillars to the extent that marketable heads were not produced.



FIGURE 8.—Class 4 plants of Charleston Wakefield variety of cabbage that did not produce marketable heads because of defects other than caterpillar damage.

In this circular plants of classes 1 and 2 are the marketable group, class 1 being regarded as extra fancy; the losses due to caterpillar damage are indicated by the class 3 plants; and the class 4 plants are those that did not produce marketable heads because of disease, hereditary factors, or unfavorable soil and weather conditions. It is considered that class 4 plants, usually being unsalable, cannot be further damaged by insects.

PRESENTATION OF DATA

INSECTICIDAL APPLICATIONS, WEATHER CONDITIONS, AND CATERPILLAR POPULATIONS

Data pertaining to dates and dosages of the various insecticidal applications, to prevailing weather conditions, and to caterpillar populations on the undusted plants at the time of these applications are given in table 2.

PLANT YIELDS

The plant yields obtained after the use of the various experimental treatments, together with information concerning the dates of the insecticidal applications composing these treatments, are shown in table 3.

TABLE 2.—*Dates and dosages of the insecticidal applications, weather conditions during period of the applications, and caterpillar populations on undusted plants shortly before the applications in experiments for the control of cabbage caterpillars, Baton Rouge, La., and Charleston, S. C., 1935-37*

FALL-CROP EXPERIMENTS

Locality and year	Date of application	Dosage per acre	Rainfall ¹	Mean temperature ²	Wind velocity ³	Relative humidity ³	Caterpillar populations per 100 undusted plants				
							Cabbage looper	Imported cabbage-worm	Diamond-back moth	Agrotine	All species
		Lbs.	Ins.	° F.	M.p.h.	Pct.	No.	No.	No.	No.	No.
Baton Rouge, 1935-----	Sept. 13	6	1.23	78	3.0	85-90	50	0	0	0	50
	Sept. 27	12	0	75	2.5	79-83	50	42	8	4	104
	Oct. 7	12	0	67	2.0	85-90	408	25	12	0	445
	Oct. 19 ⁴	14	.85	74	6.0	80-87	742	79	17	17	855
	Nov. 1	20	1.22	69	3.3	75-82	512	96	29	0	637
Charleston, 1935 (early crop).	Sept. 30	11	0	74	.9	87-91	12	0	0	12	24
	Oct. 12	11	0	66	3.6	92-93	17	0	4	25	46
	Oct. 25 ⁴	15	.24	68	.1	69-87	25	0	0	196	221
	Nov. 5	19	1.16	66	.1	92-95	79	0	12	154	245
	Nov. 13	20	.04	62	0	85-93	54	0	4	83	141
Charleston, 1935 (late crop).	Oct. 31	13	.59	64	.4	80-94	29	0	0	29	58
	Nov. 11 ⁴	19	.62	67	0	65-88	54	4	0	137	195
	Nov. 20	19	.14	57	.4	94-96	83	0	4	71	168
	Nov. 30	18	.27	45	.1	81-86	42	0	0	17	59
	Dec. 10	17	1.35	46	0	62-77	17	0	0	0	17
Baton Rouge, 1936-----	Oct. 8	0		68	2.8	82-85	83	0	0	0	83
	Oct. 19		.16	67	.7	70-80	83	0	0	0	83
	Oct. 30 ⁴		.49	61	6.0	54-60	138	4	8	0	150
	Nov. 10	21	.20	60	3.0	56-65	250	0	0	0	250
	Nov. 21	24	2.66	48	6.0	70-65	696	4	12	8	720
Charleston, 1936-----	Dec. 5 ⁴	14	5.48		14.2	82-87					
	Oct. 5	16	7.61	74	3.3	95	46	0	0	37	83
	Oct. 17	16	.03	72	0	92-96	37	0	0	34	71
	Oct. 29	20	.13	65	0	96-98	175	0	8	37	220
	Nov. 10 ⁴	21	.99	62	.2	95-84	125	0	0	29	154
	Nov. 14	23	0	59	0	95-96					
	Nov. 21	21	1.30	50	.3	91	150	0	8	13	171
	Dec. 4 ⁴	19	2.15	46	0	92-94	41	0	0	17	58

SPRING-CROP EXPERIMENTS

Baton Rouge, 1936-----	Mar. 14	7	.38	61	9.0	72	0	0	0	0	0
	Mar. 24	9	.14	59	4.6	82	4	25	12	0	41
	Apr. 3	10	2.91	66	7.1	56	0	33	25	0	58
	Apr. 13 ⁴	12	1.37	57	6.6	70	0	0	17	0	17
	Apr. 23	12	.01	66	3.8	75	4	46	37	0	87
Charleston, 1936-----	May 5 ⁴	14	.70	73	.7	80-85	4	42	100	0	146
	May 14	18	1.59	73	6.2	60-65	25	83	83	0	191
	Mar. 23	13	.46	53	.9	65-70	0	0	0	0	0
	Mar. 30	11	2.61	64	1.0	89-91	0	0	0	0	0
	Apr. 14 ⁴	17	0	61	1.7	76-85	0	0	4	0	4
Baton Rouge, 1937-----	Apr. 27	18	.17	62	.2	92-97	12	0	8	0	20
	May 11	17	.83	70	.9	94-96	21	4	12	0	37
	May 18 ⁴	16	.19	72	.2	75-80	50	50	66	0	166
	May 29	19	1.44	71	.3	92-95	466	79	195	0	740
	Mar. 23	11	1.94	59	11.2	68-71	0	4	0	0	4
Charleston, 1937-----	Apr. 2	9	.04	66	6.0	55-61	0	8	4	0	12
	Apr. 11	8	0	57	6.0	45-54	0	21	0	0	21
	Apr. 20 ⁴	18	.91	66	6.0	53-55	4	29	4	0	37
	Apr. 29	13	3.38	66	7.0	85-85	54	129	17	0	200
	Mar. 18	11	1.54	55	1.6	80-90	0	0	4	0	4
	Apr. 31	12	2.52	57	1.2	49-63	0	0	33	0	33
	Mar. 12 ⁴	19	.20	58	0	80-95	0	12	25	0	37
	Apr. 23	18	4.74	64	.2	80-95	62	17	29	0	108
	Apr. 23	16	1.49	64	1.5	93-96	254	17	71	0	342
	May 5	18	.85	69	0	98-99	146	21	42	4	213

¹ Until next application, or for a similar period in case of last application.

² Mean of 2-hour periods since preceding application, or, in the case of the first application an equal period.

³ During period of application.

⁴ Some plants began to form heads between this date and the preceding one.

⁵ Some plants were harvested between this date and the preceding one.

TABLE 3.—Plant yields, expressed in numbers and net weights (that of firm head and four wrapper leaves) of plants from the sampling areas of the six plots composing each treatment area, after the use of various schedules of application of a derris-clay dust for the control of cabbage caterpillars, Baton Rouge, La., and Charleston, S. C., 1935-37

FALL-CROP EXPERIMENTS

Locality and year	Experimental treatment No.	Dates of applications of derris dusts (0.5-percent rotenone)				Marketable plants		Unmarketable plants			
		Before heading began	Between first heading and first harvesting	During harvest	Free of caterpillar injury (class 1)	U. S. grade No. 1 (classes 1 and 2)	Caterpillar aged (class 3)	Others (class 4)	Calculated loss of marketable cabbage due to caterpillars		
Baton Rouge, 1935											
Difference required for significance when <i>P</i> equals	5	Sept. 13, 27, Oct. 7	Oct. 19, Nov. 1		Number	Tons per acre	Number	Number	Tons per acre ¹	Per cent ²	
	4	Sept. 27, Oct. 7	do		0	0	225	120	3.7	100	
	3	Oct. 7	do		0	0	213	125	3.5	100	
	2		do		1	.07	189	141	3.1	98	
	1		do		0	3	.04	164	159	2.7	98
	0	Nov. 1			0	0	.01	169	153	2.8	99
	10				0	0	115	160	1.9	100	
					(3)	(3)	51	(3)			
					(3)	(3)	70	(3)			
Charleston, 1935 (early crop)											
Difference required for significance when <i>P</i> equals	5	Sept. 30, Oct. 12	Oct. 25, Nov. 5, 18		17	1.3	25	408	.4	25	
	4	Oct. 12	do		20	83	1.5	30	.5	27	
	3		do		12	60	1.1	25	.4	29	
	2		do		16	71	1.2	33	.6	32	
	1	Nov. 5, 18			10	63	1.1	30	.5	32	
	0	Nov. 18			15	79	1.3	23	.4	23	
					(3)	(3)	(3)	(3)			
					(3)	(3)	(3)	(3)			
Charleston, 1935 (late crop)											
Difference required for significance when <i>P</i> equals	5	Oct. 31, Nov. 11	Nov. 20, 30, Dec. 10		149	5.3	3	229	1	1	
	4	do	Nov. 20, 30		174	5.5	7	204	.3	3	
	3	do	Nov. 20		187	5.6	4	203	1	1	
	2	do			139	5.0	4	219	.1	2	
	1	Oct. 31			109	4.9	10	234	.2	4	
	0				104	4.7	5	232	.1	2	
					32	.92	(3)	(3)			
					44	1.26	(3)	(3)			
Baton Rouge, 1936											
Difference required for significance when <i>P</i> equals	5	Oct. 8, 19	Oct. 30, Nov. 10, 21	Dec. 5	20	3.9	111	15	2.6	41	
	4	Oct. 19	do	do	16	149	3.5	82	1.9	35	
	3		do	do	14	163	4.1	83	31	34	
	2		Nov. 10, 21	do	7	122	2.9	125	21	51	
	1		Nov. 21	do	2	92	2.1	160	31	63	
	0			do	3	83	1.6	150	47	64	
					41	1.16	43	(3)			
					13	1.59	48	(3)			
Charleston, 1936											
Difference required for significance when <i>P</i> equals	5	Oct. 8, 19	Oct. 30, Nov. 10, 21	Dec. 5	20	3.9	111	15	2.6	41	
	4	Oct. 19	do	do	16	149	3.5	82	1.9	35	
	3		do	do	14	163	4.1	83	31	34	
	2		Nov. 10, 21	do	7	122	2.9	125	21	51	
	1		Nov. 21	do	2	92	2.1	160	31	63	
	0			do	3	83	1.6	150	47	64	
					41	1.16	43	(3)			
					13	1.59	48	(3)			

SPRING-CROP EXPERIMENTS

	5	4	3	2	1	(6)	Oct. 5, 17, 29 ¹	Nov. 10 ² , 21 ³	Dec. 4	286	406	9.0	6	12	1	1
Charleston, 1936	5	4	3	2	1	(6)	do	do	do	220	385	8.6	19	23	.4	5
							do	do	do	184	388	8.9	21	16	.5	11
							do	do	do	157	367	8.0	45	18	1.0	25
							do	do	do	120	305	6.5	20	99	2.2	24
							do	do	do	112	294	6.6	98	24	2.0	
Difference required for significance when P equals										39	35	.97	21	(²)		
										53	47	1.32	29	(²)		
Baton Rouge, 1936	5	4	3	2	1	0	Mar. 14, 24, Apr. 3	Apr. 13, 23	May 5, 14	36	294	8.3	58	14	1.1	16
							Mar. 24, Apr. 3	do	do	58	289	5.7	43	31	.8	13
							Apr. 3	do	do	39	283	5.4	59	30	1.1	17
							do	do	do	38	275	5.5	46	44	.9	14
							do	do	do	45	272	4.9	65	23	1.3	19
							Apr. 23	do	do	13	128	2.3	189	41	3.7	60
							do	do	do	20	37	.96	33	(²)		
							do	do	do	28	50	1.31	45	(²)		
Difference required for significance when P equals										222	375	7.6	7	32	.1	2
							Mar. 23, 30	Apr. 14, 27, May 11	May 18, 29	195	369	6.8	5	48	.1	1
							Mar. 30	do	do	185	366	6.8	5	42	.1	1
							do	do	do	173	362	7.1	13	39	.2	3
							Apr. 27, May 11	do	do	106	366	6.7	12	37	.2	3
							May 11	do	do	31	188	4.0	176	46	3.4	48
							do	do	do	33	32	.92	30	(²)		
							do	do	do	47	44	1.25	41	(²)		
Difference required for significance when P equals										19	169	3.9	52	14	1.1	24
							Mar. 23, Apr. 2, 11	Apr. 20, 29	do	25	146	3.0	62	29	1.3	30
							Apr. 2, 11	do	do	25	162	3.5	64	36	1.4	28
							April 11	do	do	19	143	2.8	71	36	1.5	33
							do	do	do	11	161	3.6	74	33	1.6	31
							Apr. 29	do	do	1	92	1.7	152	23	3.2	62
							do	do	do	15	46	1.11	25	(²)		
							do	do	do	20	63	1.51	33	(²)		
Difference required for significance when P equals										136	365	8.7	24	19	.6	6
							Mar. 18, 31	Apr. 12, 23, May 5	May 20	142	366	9.3	13	30	.3	3
							Mar. 31	do	do	123	365	9.1	18	24	.4	5
							do	do	do	109	353	8.5	17	37	.4	5
							Apr. 23, May 5	do	do	41	336	7.9	50	21	1.2	13
							May 5	do	do	9	235	5.4	138	33	3.3	37
							do	do	do	32	20	.91	16	(²)		
Difference required for significance when P equals										44	28	1.24	22	(²)		

¹ Based on average weight of all the marketable plants in the experiment.² Of total number of plants exclusive of class 4.³ The difference required for significance was not computed for the reason that the F test showed that the observed differences are not significant.⁴ The applications of October 5, 17, and 29 on all treatment areas of this experiment were of paris green and hydrated lime (1-9 parts, by weight).⁵ The application of November 10 was repeated on November 14 on all treatment areas involved, because a 0.99-inch rain came within 48 hours after the November 10 application was made.

DISCUSSION OF RESULTS

FALL-CROP EXPERIMENTS

The cabbage plants for the 1935 fall-crop experiment at Baton Rouge were transplanted into the field on August 27, and were harvested from November 6 to December 13. On September 27, the date of the second application of rotenone dust, there were approximately 75 cabbage webworms (*Helthula undalis* (F.)) per 100 plants in the undusted plots. Some webworms were present until harvest-time, and plant examinations made on November 1, only 5 days before the first cutting of harvest, indicated that there were approximately 42 larvae of this species per 100 plants in the plots not dusted with the rotenone mixture. This species was not included in table 2, as it was of minor importance in the other experiments. As early as September 27 imported cabbageworms and cabbage loopers were present in numbers considered sufficient to cause appreciable damage. The cabbage looper infestations developed rapidly, reaching an average of 4 larvae per plant before the plants began to head and 7 larvae per plant soon after heading began. Although actual samples were not taken, other records indicated that the heavy infestation of loopers prevailed well into the harvest period, during which time the plants were not dusted.

With few exceptions the headed cabbages on all treatment areas were so severely injured by the caterpillars that they were considered unmarketable as U. S. grade No. 1. As might be expected, however, there was a correlation between the number of heads produced and the number of insecticide applications, the correlation coefficient being 0.96, $n=4$. The heads from the dusted plots were heavier, and although approximately the same number of plants had been set into the field, there were more plants at harvesttime in the dusted plots, explaining to some extent the reason for the presence at harvest of more damaged heads in the dusted plots than in the undusted ones (table 3). None of the plants killed by the caterpillars were included in the class 3 data. Thus it was evident that the applications of derris-dust mixture increased the number and weight of the headed plants, but did not increase the yield of marketable cabbage.

The results obtained in the 1935 fall-crop experiment at Baton Rouge brought out the necessity of protecting the crop during the long harvesting period of 5 weeks. As the experiments were designed primarily to determine the number and timing of the applications necessary during the period from thinning or transplanting to the first harvesting, it was not deemed advisable to introduce experimental treatments involving the harvesting period. Therefore, in order to continue with the original objective and at the same time to prevent caterpillar damage to heads that were the last to be harvested, provision was made in later experiments for insecticidal applications on plots during the harvesting period, regardless of previous treatment. In the later experiments as many applications of 0.5-percent-rotenone dust mixture were applied (at approximately weekly intervals) during the harvesting period as the prevailing infestations indicated were necessary. In the case of the 1936 spring-crop experiments the applications made during the harvesting period

did not include the previously undusted, check-treatment areas, whereas these areas did receive the applications made during the harvesting period in the fall of 1936 at Baton Rouge and in the spring of 1937 at Charleston. In planning this later procedure the viewpoint was adopted that the experimental applications ended when the first harvesting was made and that the later applications to all plots would protect the experimental results until they could be recorded in terms of yield.

The experiment of the fall of 1936 at Baton Rouge was conducted on a cabbage planting that was seeded on August 19, thinned on October 1, and harvested during the period from November 27 to February 6. The experiment was a replicate of that of the previous fall season, with the exception that an extra application was given to all treatment areas during the harvesting period. Cabbage webworms and imported cabbageworms did not appear in appreciable numbers and, as shown in table 2, the looper infestation was not so great as that of the previous fall season. This can be attributed in part to the fact that the planting was a month later than that of the preceding fall season.

As indicated in table 3, the yield in tons per acre of marketable cabbage was significantly increased over that of the check treatment when 2 or more applications of the 0.5-percent-rotenone dust were used prior to the beginning of the harvesting period. From this standpoint there was, however, no advantage in the use of more than 3 such applications. The use of only 2 applications before harvesting began did not increase the number of marketable plants, both those of extra-fancy quality (class 1) and those of U. S. grade No. 1, or decrease the number of caterpillar-damaged plants, but the use of 3 applications did so. In general, it would appear that in this experiment the most effective treatment consisted of 3 applications prior to the harvesting period and of 1 application during that period, the first application being made when the caterpillar population was approximately 150 larvae per 100 plants. Further discussion of the results of this experiment is included in the section entitled "Economic Considerations."

The early-crop experiment of the fall of 1935 at Charleston was a replicate, as far as the dusting schedule was concerned, of that conducted at Baton Rouge during the same season. The experiment was located in a commercial field of cabbage that was seeded on August 10, thinned on September 28, and harvested during the period from November 22 to January 14. Severe infestations of *Agrotinae*, chiefly the corn earworm, developed about the time the plants began to head (table 2) and continued until the beginning of the harvest period. Twenty-three percent of the plants from the untreated areas were classed as being caterpillar-damaged. As shown in table 3, as many as five applications of derris dust failed to result in appreciable control, thus demonstrating the necessity of providing additional measures for combating corn earworms and other *Agrotinae* that are resistant to rotenone-containing insecticides.

About 3 days prior to the thinning of the plants of the early-crop experiment of 1935 at Charleston the local grower gave the entire planting an application of about 10 to 15 pounds per acre of undiluted lead arsenate. The average spacing of the plants, as thinned

by the grower, was approximately 12 inches. This close spacing resulted in a considerably larger number of plants in the sampling areas than in those of the experiments conducted on the experiment station grounds. In addition, as a result of the close and irregular spacing there was an unusually high percentage of class 4 plants.

As previously explained, a late-crop experiment was conducted during the fall of 1935 at Charleston in which the schedule of dusting was the reverse of the early-crop experiment. The planting was seeded on September 17, thinned to the desired stand on October 25, and harvested from December 19 to January 24. In this late-crop experiment the first application, and in the case of treatment No. 1 the only application, was made on all treatment areas except the check shortly after the plants were thinned (table 2). This procedure was adopted because the caterpillar infestation during the fall usually decreases with the coming of cold weather and the plants need protection most during the early part of their development. The results of this experiment indicate that no differences were demonstrated between treatments insofar as marketable or caterpillar-damaged plants are concerned (table 3). The differences in numbers of plants whose firm head and four wrapper leaves were free of injury (class 1) indicate, however, that some of the applications made during the heading period resulted in less caterpillar injury on the marketable cabbage.

The insect records for this experiment given in table 2 are of interest in that there was an average of 137 agrotine larvae per 100 plants on November 11, about the time the plants began to head. Ordinarily this infestation would seriously affect the plants; but only 2 percent of the undusted plants were damaged because the larvae were small at the time, and their further development was retarded by low temperatures. Two applications of poisoned bait, on September 18 and October 9, and the application of a 0.5-percent-rotenone dust on October 10, given the entire planting prior to the thinning of the plants, were responsible to a considerable extent for the low caterpillar population that prevailed during the experimental period.

The experiment of the fall of 1936 at Charleston was made on a planting seeded on September 1, thinned on October 2, and harvested from December 4 to January 29. The dusting procedure varied considerably from that of preceding fall-crop experiments. Since derris had been demonstrated to have practically no toxic value against the Agrotinae, it was evident that a more effective material should be used during the early part of the growing period on fall crops, the time at which these pests are most troublesome. As the arsenicals had been found to be effective against the Agrotinae in the toxicity tests, a mixture of paris green and hydrated lime (1 to 9 parts by weight) was used in all three applications made prior to the beginning of heading, and the usual mixture of derris and clay (containing 0.5 percent of rotenone) was used in all the later applications. The application made on November 10 was followed by a heavy rain and was replaced by another application on November 14. The prethinning insecticidal treatments given this planting consisted of an application of poisoned bait on September 1, and applications of equal parts of calcium arsenate and hydrated lime at rates of about

10 to 15 pounds per acre per application on September 9 and 23. These prethinning applications served to reduce the caterpillar population and probably made it easier to control the infestations that occurred during the experimental period.

In this 1936 fall-crop experiment at Charleston not over 5 percent of the plants receiving three applications of paris green and two (including the repeat application of November 14) or more applications of the 0.5-percent-rotenone dust (treatments Nos. 3, 4, and 5) were damaged by caterpillars, whereas 24 percent of the undusted plants were so damaged. The use of treatment No. 5 resulted in a greater number of marketable heads that were free of injury (class 1) but otherwise there was no significant difference between the effects of treatments Nos. 3, 4, and 5 and consequently there was little advantage in the extra applications of November 21 received by Nos. 4 and 5 and of December 5 in the case of No. 5. The low temperature that prevailed after about November 15 so reduced the caterpillar populations as to make these last two applications unnecessary. The first two applications of paris green were not adequate, as the treatment (No. 1) which received these applications alone yielded approximately the same as did the treatment (No. 0) which did not receive them. Apparently the application of paris green and lime made on October 29, just prior to the beginning of heading, and the application of derris on November 14, shortly after heading began, were necessary and were the ones chiefly responsible for the adequate control obtained in treatments Nos. 3, 4, and 5. Cabbage loopers and the Agrotinae were the chief caterpillars involved.

SPRING-CROP EXPERIMENTS

As no serious difficulties arose during the spring seasons, such as the severe damage by Agrotinae occurring during the fall, it was possible to make the spring-crop experiments at Baton Rouge and at Charleston replicates of each other,⁶ as originally planned. The plantings used at Baton Rouge during the 1936 and the 1937 spring seasons were transplanted on February 26 and were harvested from May 5 to May 28 and from May 6 to May 27, respectively. The two Charleston plantings were transplanted on February 24 and on February 12, and harvested from May 16 to June 9 and from May 10 to June 4, respectively.

In the four experiments of the two spring seasons the caterpillar infestations consisted chiefly of the cabbage looper, the diamondback moth, and the imported cabbageworm (table 2). The four plantings developed during what is considered the late portion of the commercial spring-crop season, and as a result were most likely to have the heaviest insect infestations of the season. The caterpillar populations at Charleston were greater than those at Baton Rouge, this being the reverse of what happened during the fall seasons. Weather and other conditions were such that the caterpillar populations did not develop to an appreciable extent until after the plants had begun

⁶ No applications were made during the harvesting period of the 1937 spring-crop experiment at Baton Rouge, but at Charleston the entire experimental area was given one application during the harvesting period. This difference does not affect the experimental comparisons or prevent the two experiments from being regarded as replicates.

to head, and the caterpillars were most numerous during the harvesting period. These are the conditions to be expected during the average season in the areas involved. During spring seasons following unusually mild winters, infestations have been observed to injure plants seriously before the heads had begun to form.

All the insecticidal treatments in each of the four spring-crop experiments resulted in a decrease in the yield of caterpillar-damaged cabbage and a corresponding increase in the yield of marketable cabbage (table 3). The use of more than one application of the 0.5-percent-rotenone dust prior to the beginning of harvest did not significantly increase the yield of marketable cabbage or decrease the yield of caterpillar-damaged cabbage during the 1936 spring-crop experiment at Charleston or the 1937 spring-crop experiment at Baton Rouge (treatments Nos. 1, 2, 3, 4, and 5, table 3). In the other two spring-crop experiments the treatment consisting of only one application prior to the beginning of harvest was superior in results to the check treatments, but in terms of yield of marketable cabbage per acre was inferior to one or more of those receiving a greater number of such applications. The treatments consisting of two applications prior to harvest were, however, never shown to be inferior to those consisting of three, four, or five such applications.

When cabbage of extra-fancy quality (class 1) is considered, the treatment consisting of two applications prior to the beginning of harvest was inferior to the treatment receiving five such applications in the 1936 experiment at Charleston. Otherwise the class 1 yields were in line with those of U. S. grade No. 1 plants.

It was thus apparent during the four spring-crop experiments that only the last two applications made prior to the first harvesting, together with those made during the harvesting period, were ever demonstrated to be of value in the production of U. S. grade No. 1 cabbage. In two of the experiments, that of the spring of 1936 at Charleston and that of the spring of 1937 at Baton Rouge, only one preharvesting application was shown to be of value. Evidently the earlier applications did not result in significant yield differences, because of the low caterpillar populations that existed at the time they were made and of the smaller proportion of feeding on the portion of the plants usually marketed. The maximum populations were approximately 58, 20, 37, and 37 caterpillars per 100 undusted plants, respectively, in the four experiments when these early, and what might be termed ineffective, applications were made. At the time the effective applications were begun the populations were approximately 17, 37, 200, and 108 caterpillars per 100 plants, respectively, in the four experiments. Judging from the data of preceding examinations the population in the case of the 1936 spring-crop experiment at Baton Rouge probably was actually somewhat greater than the 17 caterpillars per 100 plants found on the limited number of plants examined.

In the cases of the experiments of the spring of 1936 at Charleston and the spring of 1937 at Baton Rouge the treatment (No. 1) consisting of one application of a 0.5-percent-rotenone dust, made 5 days before harvest began at Charleston and 7 days before harvest began at Baton Rouge, proved the most efficient, considering the number of applications made. At Charleston this treatment was followed

by two applications at approximately 10-day intervals during the harvesting period and resulted in adequate control of the caterpillar population as indicated by the fact that only 3 percent of the plants were classed as being caterpillar-damaged, whereas 48 percent of the undusted plants were so damaged. The effectiveness of the control obtained in this experiment is illustrated in figure 9. In the aforementioned Baton Rouge experiment no applications were made during the harvest period, and although the use of treatment No. 1 reduced the caterpillar-damaged plants from the 62 percent in the case of the undusted plants to 31 percent, the control obtained is not considered as being adequate. As the Charleston treatment provided adequate control of a greater caterpillar population it would appear that the 0.5-percent-rotenone dust would have provided similar control at Baton Rouge had the plants been protected during the harvesting period.

The most efficient of the treatments compared during the two other spring-crop experiments, that of 1936 at Baton Rouge and of 1937 at Charleston, is regarded as being that treatment (No. 2) consisting of two applications of the 0.5-percent-rotenone dust made 22 and 12 days, respectively, before harvest began at Baton Rouge and 5 and 17 days, respectively, before that period at Charleston. This treatment was followed by two applications during the harvesting period at Baton Rouge and by one such application at Charleston. The treatment reduced the caterpillar-damaged plants from 60 percent in the case of the undusted check to 14 at Baton Rouge, and from 37 percent in the case of the check treatment (which received one ap-



FIGURE 9.—Effectiveness of caterpillar control obtained during the experiment of the spring of 1936 at Charleston, S. C. Plot 2A received four applications of a 0.5-percent-rotenone dust; the adjoining plot, 3A, received no insecticides.

plication during harvesting) to 5 at Charleston. The control obtained at the latter place is regarded as being adequate for commercial purposes.

Although the relative degree of caterpillar control obtained from the use of the various treatments was approximately the same in comparable experiments (chiefly those of the spring seasons) at Baton Rouge and at Charleston, it was apparent that adequate control was more closely approached at Charleston. Some possible contributing factors are evident from the data given in table 2. For example, at Baton Rouge the insecticide applications were somewhat lighter in dosage and were accompanied by greater wind velocities and lower relative humidities, the differences in wind and moisture possibly being due to the fact that the applications were begun earlier in the afternoon at Baton Rouge. In addition it should be stated that the foliage of the Copenhagen Market variety of cabbage grown at Baton Rouge does not grow as upright as that of the Charleston Wakefield variety used at Charleston. This growth habit, plus the fact that the Copenhagen Market leaves have a greater tendency to overlap the buds loosely, tends to provide the caterpillars with better protection from the insecticides. The failure in some cases to obtain adequate control with a 0.5-percent-rotenone dust demonstrated the need for tests of more frequent applications of derris dusts containing higher percentages of rotenone.

ECONOMIC CONSIDERATIONS

To determine the true value of any treatment the cost must be considered and the true increase in yield must be determined and given a monetary value. The observed increase in yield resulting from a treatment is subject to sampling fluctuations and is therefore only an estimate of the true increase. It is possible, however, to calculate the range above and below the observed increase in which the true increase falls with a given probability.

The experiment at Baton Rouge in the spring of 1936 is taken as an illustration. It was found that the mean difference between the yields of treatment No. 1 and the check was 2.58 ± 0.46 tons per acre of U. S. grade No. 1 cabbage and that the least difference between the yields that would be regarded as significant for odds of 19 to 1 was 0.96 ton. The range of the increase, in tons, is from 1.62 to 3.54, as determined by subtracting 0.96 from 2.58 and adding 0.96 to 2.58. To be conservative in estimates of profit, most emphasis will be placed on the lower limit.

A study of average prices to growers over a period of years indicated that \$20 per ton is a representative value for cabbages in the field. At this price the range of from 1.62 to 3.54 tons of marketable cabbage would be worth from \$32.40 to \$70.80. The cost of the three applications of 0.5-percent-rotenone dust that constituted the experimental treatment was approximately \$7.20. When this cost of treatment is subtracted, the net increase in yield is found to be worth from \$25.20 to \$63.60. Thus the true net profit may have been as low as \$25.20. Similar calculations showed that the four earlier applications made during the preharvesting period merely paid for them-

selves without leaving appreciable profit and might not be advisable unless plants of extra-fancy quality were desired or the caterpillar population was greater than in this case. The same calculations were made for the other experiments conducted in the spring and the results are summarized in table 4.

TABLE 4.—*Plant yields, number and estimated costs of applications involved, and net profits resulting from the use against caterpillars on small experimental plots of spring-crop cabbage of a derris dust containing 0.5 percent of rotenone, Baton Rouge, La., and Charleston, S. C., 1936-37*

Location and year	Applications ¹	U. S. grade No. 1 yields			Cost of treatment per acre (current)	Net profit per acre	
		Dusted plots	Undusted plots	Mean difference ²		Observed mean value	Expected range in value ³
	Number	Tons per acre	Tons per acre	Tons per acre	Dollars	Dollars	Dollars
Baton Rouge, 1936.....	3	4.86	2.28	2.58±0.46	7.20	44.40	25 to 64
Charleston, 1936.....	3	6.66	3.95	2.71±.44	7.20	47.00	29 to 65
Baton Rouge, 1937.....	1	3.60	1.69	1.91±.53	2.40	35.80	14 to 58
Charleston, 1937.....	4 ⁴	7.83	5.38	2.50±.44	2.40	47.60	29 to 66

¹ In each case 1 application was made about a week prior to the beginning of harvest. Where other applications were made they came during the harvesting period.

² Standard error of the difference appears after each mean difference.

³ Based on the limits of the mean yields for a probability of 5 percent.

⁴ An additional application of a 0.5-percent-rotenone dust was made to all plots, including the checks, during the harvesting period to preserve the crop from further insect damage until the yield could be determined.

The yields of U. S. grade No. 1 cabbage obtained during the course of the spring experiments at Charleston (table 3) closely approached the 10-year average (1928-37) yield of 9 tons per acre of the "secondarily" cabbage-producing areas. The Baton Rouge yields were considerably below that figure.

Results obtained from the fall-crop experiments were somewhat different from those of the spring crops. None of the treatments tested during the fall of 1935, either at Baton Rouge or at Charleston, resulted in economic increases in yield. The most effective and efficient of the treatments tested in the fall of 1936 at Baton Rouge was that (No. 3) consisting of three insecticide applications between the beginning of plant heading and the first harvesting, followed by one application during the harvesting period. If the method of calculation employed for table 4 is used, there was an increase of at least 1.3 tons per acre of U. S. grade No. 1 cabbage, having a value of approximately \$26, resulting from the use of treatment No. 3 in this experiment. Deducting \$7.20 for the cost of the treatment the net returns would be approximately \$19. Applications prior to heading of the plants did not materially affect the yield of marketable cabbage.

In the Charleston 1936 fall-crop experiment the most valuable treatment was that (No. 3) in which three applications of paris green and hydrated lime (1 to 9 parts) were made between the thinning and first heading of the plants, and two applications of the 0.5-percent-rotenone derris dust shortly after heading began. The increase due to this treatment over the treatment consisting of no application was at least 1.3 tons per acre of U. S. grade No. 1 cabbage.

SUMMARY AND CONCLUSIONS

Previous investigations by the authors demonstrated that insecticides containing arsenic or fluorine should not be applied to cabbage after the heads begin to form, and subsequent investigations demonstrated the effectiveness of a mixture of derris-root powder and china clay containing 0.5 percent of rotenone in reducing caterpillar infestations.

A series of experiments was conducted on small plots of cabbage arranged in Latin squares at Baton Rouge, La., and Charleston, S. C., from the fall of 1935 to the spring of 1937, inclusive, to determine the effectiveness of from one to five applications of a derris-clay dust mixture containing 0.5 percent of rotenone in reducing caterpillar injury and damage and in increasing the yield of marketable cabbage. The caterpillars against which the insecticide applications were directed consisted chiefly of the cabbage looper (*Autographa brassicae*), the diamondback moth (*Plutella maculipennis*), and the imported cabbageworm (*Pieris rapae*). The cultural practices and varieties of cabbage grown were those employed and used in the respective localities.

The dust mixture was applied with hand-operated, rotary dust guns at the rate of from 6 to 24 pounds per acre, depending upon the size of the plants. One experimental treatment consisted of withholding all applications during the experimental period. For the one-application treatment the application was usually made shortly before the beginning of harvest. For the two-application treatment one application was made as above and the other about 12 days preceding it. For the three-, four-, and five-application treatments the applications were timed in like manner at intervals of about 12 days. This resulted in extending the five-application treatment over the experimental period from soon after the thinning or transplanting of the plants in the field to the beginning of harvest.

The effectiveness of each treatment was determined after the plants were harvested, when each plant was classified according to damage by caterpillars and eligibility to be sold as U. S. grade No. 1 cabbage. For this purpose damage was considered as caterpillar injury of such a nature or extent as to cause a plant to be ineligible to U. S. grade No. 1.

In the fall of 1935 the treatment consisting of five applications of derris dust applied prior to the beginning of harvest resulted in practically no reduction in numbers of damaged heads or increases in yield. At Baton Rouge, La., excessive numbers of cabbage loopers fed on the cabbage during the prolonged harvesting period when no insecticides were applied. This showed that in conducting future experiments it would probably be necessary to protect the fall crop of cabbage during the prolonged harvesting period which usually extends over 3 or 4 weeks. In the experiment at Charleston, S. C., most of the damage was unexpectedly caused by the corn earworm (*Heliothis armigera*) and other species of the subfamily Agrotinae, demonstrating that they are not controlled satisfactorily by the use of derris.

The most efficient treatment tested in the fall of 1936 at Baton Rouge, La., consisted of three applications of the derris dust made

between the time the first heads began to form and the beginning of harvest. This treatment resulted in an increase in yield over the check treatment of at least 1.3 tons of marketable cabbage per acre having a value of approximately \$26.

At Charleston, S. C., in the fall of 1936, paris green and hydrated lime (1 to 9 parts by weight) was substituted for derris dust in the early applications, and the timing of the applications differed from that in the other experiments. The most valuable treatment consisted of three applications of the paris green dust prior to the formation of the first heads, followed by two applications of the derris dust during the heading period. This treatment resulted in an increase in marketable cabbage of at least 1.3 tons per acre.

In the experiments conducted on the spring crops of 1936 and 1937 at Baton Rouge, La., and Charleston, S. C., it was found that in most instances it was not profitable to apply the derris dust earlier than just prior to the beginning of harvest. One or more applications made after this time always resulted in a significant decrease in the number of caterpillar-damaged plants and a corresponding increase in the yield of marketable plants. It is estimated that in the four spring-crop experiments the increase in yield due to the later applications was at least from 0.80 to 1.79 tons per acre, and the approximate net profit was at least from \$14 to \$29 per acre. In two of the experiments, however, the degree of caterpillar control obtained was not entirely adequate.

In general, the investigations indicated a need for further studies to determine whether derris dusts containing higher rotenone content or applied more frequently with a corresponding increase in cost could be employed profitably by the grower in a control program for cabbage caterpillars.

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<i>Bureau of Entomology and Plant Quar- antine.</i>	P. N. ANNAND, <i>Chief</i> .
<i>Division of Truck Crop and Garden Insect Investigations.</i>	W. H. WHITE, <i>Principal Entomol- ogist, in Charge</i> .

